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Non-destructive testing - Coercivity testing method for static equipment in petroleum and chemical plants

无损检测 石化化工装置静设备矫顽力检测方法

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Foreword

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04 Nondestructive testing of coercivity of static equipment in petrochemical plants Detection methods Released on 2026-05-

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1.Scope This document describes the coercivity testing method for static equipment in petrochemical plants, specifying the principle, testing equipment, and test blocks for coercivity testing. Testing process specifications, pre-testing preparation, testing implementation, evaluation of test results, and testing records and reports. This document applies to static design specifications for pressure vessels, pressure pipelines, and large atmospheric pressure storage tanks made of carbon steel or low alloy steel in petrochemical plants. Coercivity testing of equipment. Coercivity testing of rotating equipment in petrochemical and chemical plants and other industries should be conducted in accordance with this procedure.

4 Principles

4.1 Coercivity Coercivity is a quantitative reflection of the pinning effect of magnetic domain walls, and the coercivity test results are closely related to the microstructure of the workpiece itself. Factors such as body-centered cubic crystal structure, doping with alloying elements, grain refinement, second-phase precipitation, and dislocation multiplication can all increase coercivity; it is also affected by... The physical properties of the workpiece being inspected also have an impact; for example, for the same material, the smaller the wall thickness, the greater the coercivity. Simultaneously, the load conditions of the workpiece will also significantly affect the coercivity. Effects include the influence of stress on coercivity; in addition, the heat treatment process and service condition of the workpiece under inspection can also indirectly affect coercivity. Effects such as quenching heat treatment, damage accumulation, and material aging can all increase coercivity. The coercivity detection principle is shown in Figure

1.An excitation coil and a detection coil are wound around a U-shaped magnetic yoke, forming a magnetic probe with a Hall sensor. The head contacts the workpiece to form a closed magnetic circuit. Under the action of a positive excitation magnetic field, the magnetization direction of the detection area of the workpiece will be unified with the positive magnetic field. When the magnetic field is applied in the direction of the magnetic field and the magnetic domains reach saturation magnetization, a reverse demagnetizing field is applied, and the magnetic domains begin to reverse magnetization until the magnetic induction intensity decreases. The voltage is zero. The Hall sensor, in conjunction with the detection coil, acquires the voltage signal generated by the change in the magnetic field of the workpiece being inspected, which is then converted into a recognizable signal by the acquisition module. The digital signal is input into the host, and the data processing software automatically calculates the corresponding coercivity value.

4.2 Relationship between coercivity and stress Based on the force-magnetic coupling effect, the magnetic domain structure and domain wall motion at stress concentration sites in materials undergo significant changes under the action of a magnetic field, leading to coercivity When the force signal changes abruptly, such as under quasi-static tensile conditions, the relationship between the coercive force in the parallel stress direction and the uniaxial stress of a low-carbon steel specimen is given by formula (1).

5 Testing equipment and test blocks

5.1 Detection System The coercivity testing system is shown in Figure 2.A suitable magnetic probe is selected based on the characteristics of the workpiece being inspected, and the excitation module is controlled by the host computer to generate... A sufficiently large current is applied to the excitation coil to generate a pulsed magnetic field, causing the inspected workpiece to reach a localized saturation magnetization state before demagnetization. Hall effect sensor The sensor and detection coil work together to collect the electrical signal generated by the change in the magnetic properties of the workpiece under inspection, and the signal acquisition module converts it into a digital signal input. The host computer, after being processed by data analysis software, yields the coercivity test results.

5.2 Magnetic Probe

5.2.1 Magnetic Probe Function The magnetic probe should be capable of locally saturating and demagnetizing the inspected workpiece, and should also be able to measure magnetic field strength and magnetic induction. The function of responding to intensity signals.

5.2.2 Selection of Magnetic Probe The magnetic probe should be selected based on the wall thickness of the workpiece being inspected, while also considering the surface condition of the workpiece, such as flatness and surface curvature. Magnetic probes can be customized according to the surface condition if necessary.

5.3 Testing Instruments

5.3.1 General Requirements The testing instruments should meet the following requirements.

a) Automatic acquisition, calculation, storage, and display of measurement signals;

b) The relative error of measurements at the same location shall not exceed 5%;

c) The excitation current is not less than 2 A;

d) Powered by lithium batteries, with a continuous working time of not less than 8 hours.

5.3.2 Instrument Modules and Functions The excitation module primarily magnetizes the workpiece by controlling capacitor discharge to generate a pulsed magnetic field. The signal acquisition module then converts the electrical signal... After noise reduction and digitization, the data is input to the host computer. The host computer controls the operation of all modules in the entire detection system and calculates the coercivity using data processing software. Force value.

5.4 Calibration test block Calibration blocks possess specific magnetic properties to verify and maintain testing accuracy. Calibration blocks should be manufactured from carbon steel or alloy steel. The material is uniform and the surface is smooth and flat, so avoid impact or heat. The calibration test block should be a square block, as shown in Figure 3, and should cover the entire probe area. Minimum dimensions are shown in Table

1.Low-magnetic-characteristic carbon steel calibration test block. The coercivity should not exceed 400 A/m, and the high magnetic property alloy steel calibration test block should be subjected to quenching and tempering heat treatment, with a coercivity of not less than 2,500 A/m. The calibration block should be reviewed annually, with checks including its geometric dimensions and magnetic properties. The maximum permissible error in the geometric dimensions of the test block is not significant. Within

0.5 mm. Magnetic properties should be verified by a third-party organization in accordance with GB/T 13888.

5.5 Comparative test block The comparison test block is used to establish a calibration curve for coercivity versus stress, and to test the sensitivity of the detection system during use, satisfying the following requirements. Require.

a) Design a comparison test block based on the workpiece under inspection, and prepare the comparison test block according to GB/T 228.1;

b) The material, surface quality, heat treatment state, and magnetic properties of the comparison test block are the same as or similar to those of the workpiece under inspection;

c) Sensitivity testing was conducted using a uniaxial tensile test, with an applied elastic stress range of (0~0.9)sy, and at least 5 stresses were set. At the measurement points, record the coercive force values corresponding to different stresses and plot the calibration curve;

d) Determine the curve fit using linear regression, with sensitivity measured by the coefficient of determination R^2, which must be no less than 0.9;

7 Preparations before testing

7.1 Data Inquiry The following information should be consulted to understand the relevant details of the equipment.

a) Manufacturing-related documents of the inspected workpiece. product certificate, quality certificate, and as-built drawings, with a focus on understanding its structural features and materials. feature;

b) Operation records of the inspected workpiece. operating process parameters, years of operation, and any abnormal situations that occurred during operation;

c) Inspection data of the inspected workpiece. inspection and testing records and reports from previous years;

d) Other materials. relevant documents for maintenance, repair and modification.

7.2 Site Survey On-site inspections should be conducted in the following situations.

a) Analyze the potential stress concentration points on the workpiece under inspection, identify the inspection area, and mark its location;

b) Identify and eliminate all interfering factors that may affect the test results;

c) The operating environment should be free of factors that could affect personnel safety.

7.3 Determination of Detection Method Depending on the purpose of the inspection and the structural characteristics of the workpiece being inspected, the inspection methods generally include the following.